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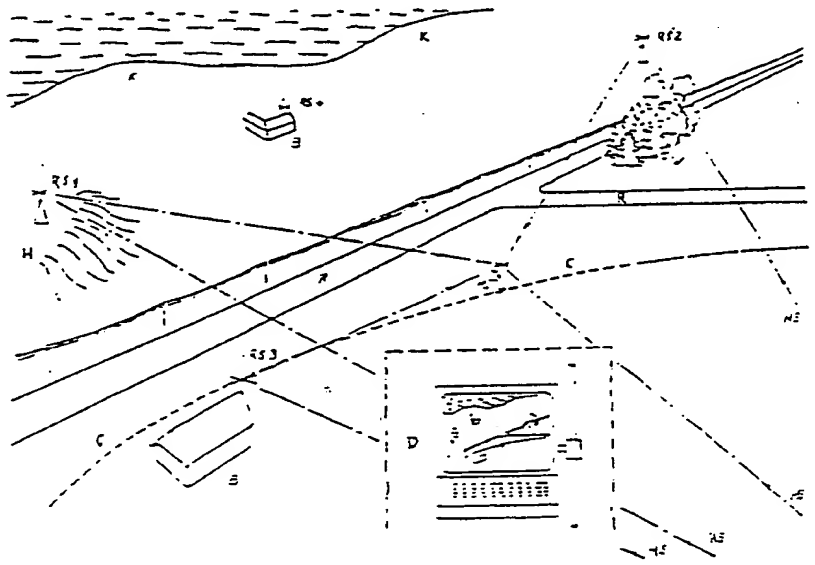
(54) Title: A SYSTEM FOR LOCALIZING LAID CABLES OR PIPES

(57) Abstract

A system for localizing laid cables (C) or pipes by means of a system of transmitters comprising one or more fixed or mobile base stations (HS). At least one of the stations are provided with an electronic data processor and a number of relay stations (RS 1, RS 2, RS 3), some of which or all are fixed with exactly known geographic placements. Besides there are one or more measuring stations (MS) which can communicate with the base station (HS) and receive positioning signals from the relay station (RS 1, RS 2, RS 3). By request from a measuring station (MS) the base station (HS) can activate positioning signals from a selected group of relay stations (RS 1, RS 2, RS 3). The measuring station (MS) is provided with means of measuring the differences between times of arrival of the signals from the activated relay stations (RS 1, RS 2, RS 3) and to re-transmit the measuring resi to the base station (HS) which by means of the computer's memory converts the geographic data of the measuring res In case cables (C) or pipes are laid, these data are entered into the data store, and in case a cable or a pipe is recovered data are retransmitted to the measuring station (MS) together with such geographic information which is necessary fc complete orientation.



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A System for Localizing Laid Cables or Pipes

The localization of buried pipes or cables, in case a defect should make a digging up necessary, normally is carried out as follows: At the laying the pipes or cables are mapped out and by means of the map it is possible to reach the approximate placement by measurement. If time-consuming attempts to dig them up must be avoided the mapping-out must be very accurate, and as cables and pipes have to be laid at places where the marking poles are not left undisturbed, very exact surveying has to be carried out, each time the cables or the pipes must be recovered.

The object of the invention is to produce a radio installation by means of which it is not only possible to determine the geographic placement of a pipe or a cable, but also to locate any point on the pipe or the cable with a so high degree of accuracy that they can be recovered without any previous trial digging being necessary.

Locating fixed or mobile objects by means of radio waves is a well-known method. The U.S.A. patent specifications No. 3 848 254 thus for instance relate to a method of locating vehicles, viz. as follows: A central station transmits a signal to a transmitter in the vehicle; the signal starts the transmission of pulses, which are modulated by means of a carrier wave. This carrier is received by a number of fixed stations which demodulate the signal and transmit it to the central station where a comparison of phases is made and consequently a position determination is calculated.

This and other fámiliar methods of radio location cannot be used for the present purpose, because the following demands must be met:

1) The geographic data of the laid cables/pipes have to be kept permanently and in such a way that they can be visualized in the form of a map containing information about coast lines, roads, land register boundaries etc.

2) At least the mobile station being used for recovering the cable/pipe must be able to receive the necessary data for an orientation in relation to characteristic features of the landscape or the buildings in the area concerned.

3) The mobile station must be so light that it can be carried by one person without difficulty and that it can be operated by personnel without special training.

The third condition implies that the transmitter output of the mobile station is small and the second condition implies that calibrations and interpolations must be carried out automatically and without weighting the mobile station with heavy EDP equipment

According to the invention - as it is the case for the well known system above - a system of transmitter-receiver stations is used, viz. a system consisting of one or more fixed or mobile base stations with computers, and a number of relay stations, some of which or all are fixed with exactly known geographic co-ordinates, and one or more mobile measuring stations which are able to communicate with the base station and to receive positioning signals from the relay stations. It is characteristic of the invention that a base station, when demanded by a measuring station, initiates the transmission of positioning signals from a selected group of relay stations to the base station, which forwards the result of the positioning to the base station

which converts it to a geographic localization on the basis of data stored in the computer's data store. When cables or pipes are laid the localization must be registered and with the purpose of the recovery of the buried cable/pipe, the localization together with the characteristic geographic data of the spot concerned must be reproduced thus marking the position of the cable/pipe.

The base station may and ought to have means for controlling the accuracy of the localization. The propagation speed of radio waves varies in accordance with the temperature and the humidity of the air. Polarizing direction and phase may be altered by reflections from buildings and metallic items.

On a very hilly ground or when relay stations permanently or provisionally are placed upon high buildings, differences of height may play a role what the accuracy of measurement is concerned. It is obvious that the localization is not necessarily a correct geografphic mark. The co-ordinates of a certain point of measurement, which has been determined by means of radio waves from two or more relay stations, must be reproducable with the demanded accuracy, viz. that the reading when the measuring station is at a certain position must be unambiguous for this very position and differ from the reading of any other position. However as it is not sure that the localization is made by means of the same group of relay stations as well at the recovery as at the laying a correction as to differences of height may be necessary. This correction can be carried out as follows: Two relay stations' aerials are placed with a known difference of height, so that it is possible to correct for the difference in height on the basis of the time difference between the arrival of the signals from the two aerials. It is also possible to store topographical data in the com-

puter's memory so that the corrections can be carried out automatically.

If provisional relay stations are used these may have a measuring equipment corresponding to those of the mobile measuring stations, so that their placing in relation to the permanent relay stations can be determined and input into the computer's program library. It may be important to provide all relay stations with such an equipment which can be activated from the base station. By treating the single relay stations as measuring stations the base station can determine their reciprocal distances . If the data achieved by that do not coincide with stored data, corrections for changes in the propagation speed of the radio waves due to atmospferics may be calculated.

As mentioned above the mobile measuring station should not be heavier than that it can be carried by a single person, and therefore it should only contain the equipment which is necessary for the communication with the base transmitter and for receiving signals from neighbouring relay stations plus the required electronic counters to measure the relative hours for the arrival of signals. These counters may be started by the first signal to arrive, but may also be started by a signal coming from the base transmitter.

Indication of the cable/pipe or of the spot where the measuring station is placed may be carried out like this: In continuation of the measuring station's aerial a "pointer" is put, for instance a telescopic tube, with which the operator points at the cable/pipe , and at the same time a signal is transmitted to the base station, telling it that now the result of a position measurement or a request for a position indication is coming.

When the cable/pipe is laid the intervals between the markings may be made independent of how rectilinearly the cable/pipe is laid at the spot in speech, the computer of the base station being able to determine any point on the cable/pipe by interpolation. The lengths of the intervals may be appointed on the operator's rough estimate, but the mobile station may also be prepared for mounting on the cable plough or on the furrow excavator, and the tractor of these may be provided with devices for electronic measurement of the driving speed and the turning of the steering wheel and these measurements then automatically control the intervals between the position indications.

Communication between base station and measuring station may be performed in different ways. If the base station is manned, which is not necessary, a conversation may be carried out in the normal manner and the operator may bring a map of the district in question. Such an off-line communication is not practical. Besides the necessary time-metering equipment the measuring station ought to be provided with a display unit and at least one of the base stations ought to have means of recording the geographic data of the district concerned in the form of draft maps while a marking of a laid cable/pipe and a marking of the the position of the measuring station are made. Communication with the base station may be performed by means of a simpel keyboard. In short the measuring station may be made as an "intelligent" terminal for the base station's memory.

A realization of the invention will be explained in the following, referring to the drawing where

Fig. 1 schematically shows a system according to the invention.

Fig. 2 shows a simplified block diagram of a measuring station.

Fig. 3 shows a simplified block diagram of a base station and

Fig. 4 shows a block diagram of automatic excitation of the generation of geografic coordinates during cable-laying.

Fig. 1 shows symbols of some landscape elements, which normally are indicated on a map: Buildings B, rises or hills H, larger wooded areas W, roads R and coast lines K. Around in the terrain shown relay stations RS1-RS4 are placed. As it is shown their aerials may be placed on roofs, hilltops or buildings especially made for this purpose.

Fig. 1 shows a mobile measuring station MS being used to trace a buried cable, which is indicated by the dotted line C. All the stations communicate - as indicated by the dot-and-dashed lines - with a base station HS not shown. When demanded by the person operating the measuring station the base station transmits a draft map to the measuring station, where it is shown on the display unit D. The mobile station and its display unit are shown on an x) 1. Simultaneously the base station starts a cyclic activation of a number of relay stations, on the figure RS1, RS2 and RS3, which in turn transmit distance-determining signals, which are received by the measuring station. The last-mentioned measures the hour when the signals arrive in relation to an hour of reference, which e.g. may be the hour when the first signal arrives. The result of the measurement is transmitted to the base station HS, which knowing the placing of the relay stations and the topographical

x) enlarged scale at the bottom of Fig.

conditions converts the result to co-ordinates appearing on the display unit D. The display screen also shows the carrying of the cable together with the point of the cable which is to be inspected. The length of the cable from a fixed point to the defective spot has been measured by means of a usual error-measuring equipment, and as the length of the cable from one marking point to another is a known data in the memory, the position of the defective spot may easily be calculated.

When the mobile station has come sufficiently near the point wanted the base station may change from the draft map to a system of co-ordinates which corresponds to an area of a few square meters round about the defective spot and therefore allows a localization which is sufficiently accurate to indicate the spot where the cable may be recovered by digging.

The surest localization is obtained by the use of three relay transmitters at least. As an example it is assumed that RS1, RS2 and RS3, being controlled in cyclic sequence by the base station, are activated to transmit brief pulses of ultra-high frequency. These are received by the measuring station which provides the time-differences $t_2 - t_1$, $t_3 - t_2$ and $t_3 - t_1$ for an adequate number of pulse cycles and transmits the result to the base station which then calculates the mean value and the standard deviation of the results measured. If the standard deviations exceed the accuracy of measuring claimed they must be cancelled and new measurements be made, perhaps by activating more or other relay transmitters. Two of the three time-differences will do for a localization, but the third one should be taken in consideration as a control. If differences of height must be corrected for, the third difference must be taken in consideration.

Fig. 2 shows a very simplified diagram of the mobile measuring station. The basic elements of this station is

an aerial 1 which by means of the switches 2 may be connected to either a transmitter 3 or to a receiver 4. The receiver is through a demodulator 5 connected to a control unit 6 which is provided with a display unit 7 and a micro telephone 8. The control unit 6 is also connected to the transmitter 3 through a modulator 9. In the control unit the electronic counters are built-in. They determine the relative time of arrival of the pulses from the relay transmitters and also the fixed "instructions" necessary for the measuring station's functioning as a data terminal.

As Fig. 3 shows the base station in broad outline consists of a transmitter 10 and a receiver 11, which both are connected to a control unit 12 through a modulator 13 and a demodulator 14 respectively. The control unit has incorporated the organs necessary for manual and automatic operation, i.e. it functions as the central control unit for inputting and outputting data and their processing. The control unit has access to a data store 15. This data store may be common for several base stations and part of the necessary equipment for processing the in-coming and the out-going data may also be common.

An essential advantage of the invention is that the geographical data of a laid cable can be obtained from the same equipment which is used for the recovery, in other words, the data necessary for the recovery can be produced by the same equipment as that explained in the general part of this description. It is important that the memory of the base station not be filled with unnecessary position indications. According to the invention - and as already mentioned - the distances between the marking points can be varied corresponding to the cable having been laid almost rectlinearly or in curves. The principle is shown schematically in Fig. 4 where there is a device 16 which measures the turning angle of a tractor, and a device 17 measuring the turns of a tractor's wheel and through that

the driving velocity. The values obtained are converted into electric pulses which control the frequency of a pulse generator 18, and for each pulse the generator causes activation of the measuring station 19 as described in Fig. 2.

Claim

1. A radio locating system of the sort which uses at least two stationary stations and one mobile station, and by means of which, going out from known distances between stationary stations and the propagation speed of radio waves and/or phase conditions, one is able to calculate the placing of the mobile station in relation to that of stationary stations, c h a r a c t e r - i z e d b y the fact that the momentary place of the mobile station is communicated to and from a data base by a graphic computer system containing positions of coast lines, ridges, roads, land register boundaries, houses, pipes, cables etc., and that a computer being placed stationarily or mobilly calculates the momentary position of the mobile station and - in case the answer is wrong - adds one or more supplementary measurements to other stationary stations or informs the user of the mobile station of the erroneous value, and that the mobile station can communicate with the user by means of writing or conversation.

2. A system as claimed in Claim 1, c h a r a c t e r - i z e d b y the system itself communicating the necessary data to and fro between the data store and the mobbile equipment.

3. A system for the localization of buried cables or pipelines by means of a system of transmitting stations, comprising one or more fixed or mobile base stations of which at least one has got an electronic data processor

and a number of relay stations, some of which or all are fixed with exactly known geographic placings and one or more measuring stations able to communicate with the base station and to receive positioning signals from the relay station, c h a r a c t e r i z e d b y the fact that the base stations when requested by a measuring station can initiate transmission of positioning signals from a selected group of relay stations, and that the measuring station has means of measuring the differences of the times of arrival of the signals from the activated relay stations and of re-transmitting the measuring results to the base station which - by means of the memory of the computer - converts the geographic data of the obtained value, which in case of cable or pipe laying are entered in the data store, and which in case the cable or pipe is recognized, are re-transmitted to the measuring station with the geographic data necessary for a complete orientation.

4. A system as claimed in Claim 3, c h a r a c t e r - i z e d b y the base stations having means of controlling the accuracy of the measuring results and of causing transmission of signals from other realy stations in case of possible inaccuracies.

5. A system as claimed in Claim 4, c h a r a c t e r - i z e d b y the stations being equipped with instruments such as light meter, hygrometer, barometer, thermometer etc. for recording the weather conditions during the measurement and by these data forming part of the processing of the measured result in the computer.

6. A system as claimed in the Claims 4 or 5, c h a r a c - t e r i z e d b y the fixed stations being equipped with instruments recording the direction, velocity and force of the wind and especially recording the aerial mast's swings, and these data forming part of the processing of the measured result in the computer.

7. A system as claimed in Claim 4, c h a r a c t e r i z e d b y the stations having means of taking into account the natur of the environments/ landscape in which the measurements are performed.

8. A system as claimed in Claim 5, c h a r a c t e r i z e d b y the controls incorporating means of automatic correction of differences in altitude between the aerials of the relay stations and that of the measuring station.

9. A system as claimed in Claim 8 c h a r a c t e r i z e d by the fact that relay stations being placed in a very hilly terrain transmit signals from two aerials mounted one above the other, the distance between being known.

10. A system as claimed in any of the foregoing claims, c h a r a c t e r i z e d b y the fact that at least the unpermanently placed relay stations are provided with an equipment like that of the measuring stations, which is able to determine their placing in relation to other realy stations.

11. A mobile measuring station to be used in a system as claimed in any of the foregoing claims, c h a r a c t e r i z e d b y being worked out as the data terminal of a base station.

12. A base station as claimed in Claim 11 c h a r a c t e r i z e d b y having a "pointer" in the form of a telescopic tube which is mounted so that it determines the plumb line of the station's aerial.

13. A measuring station as claimed in Claim 11 c h a r a c t e r i z e d b y being made for mounting on a cable plough or an excavator, the tractor of which is equipped with measuring devices for the measurement of its driving velocity and the turn of its steering wheel and for converting the obtained values into electric signals controlling a pulse generator which by each pulse activates the production of a position determination by means of the activated relay stations and the recording of the position determinations in the base station's memory.

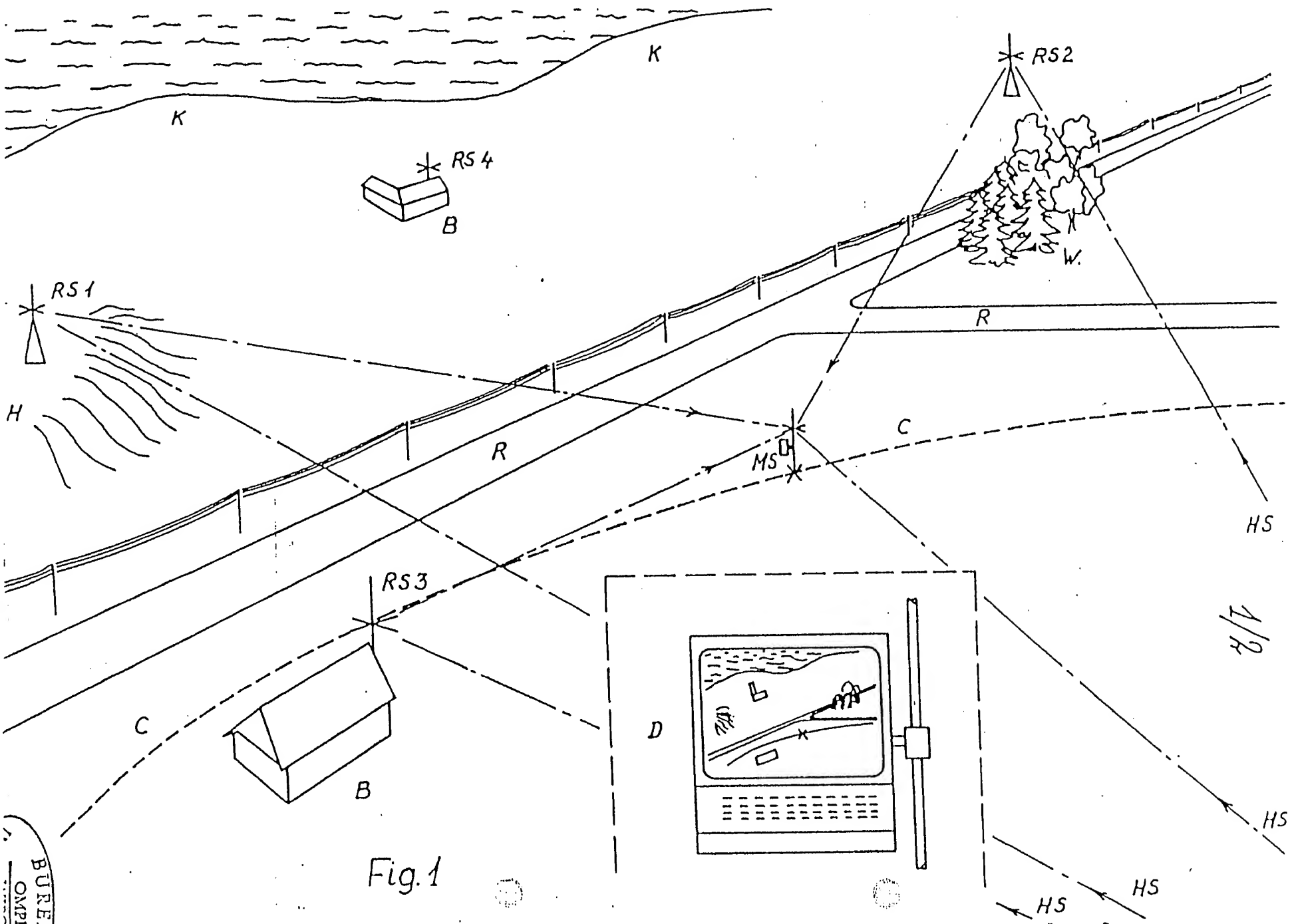

Fig. 1

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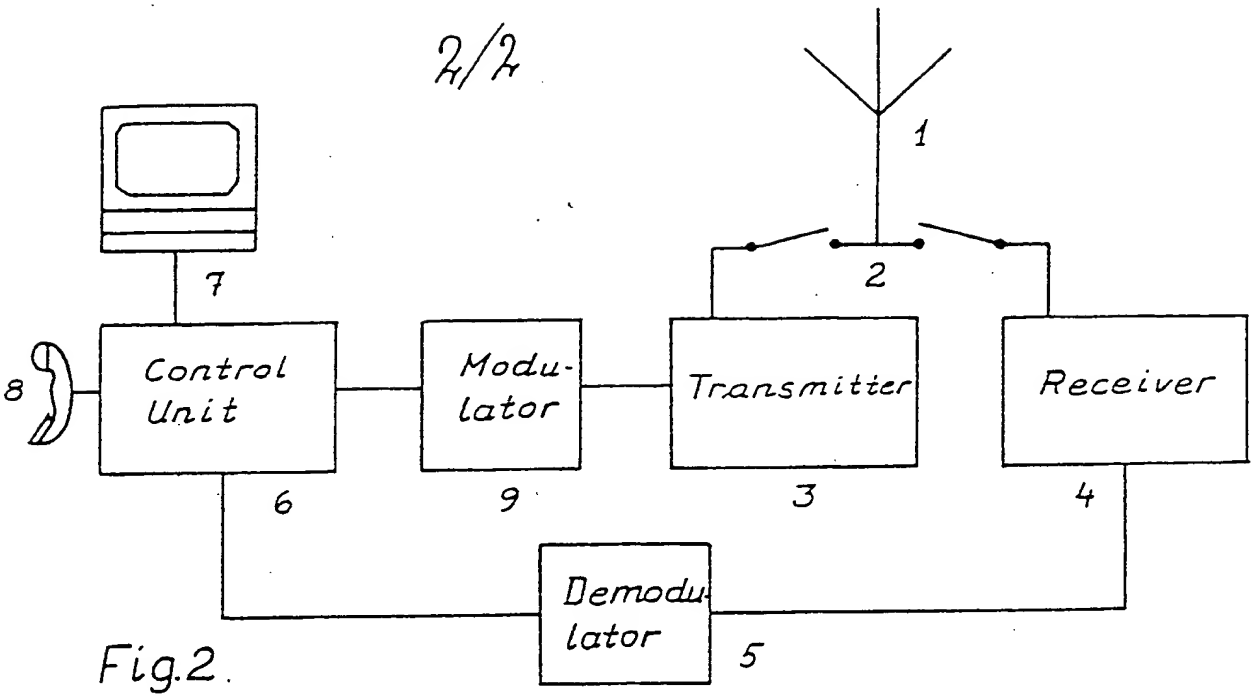

Fig.2.

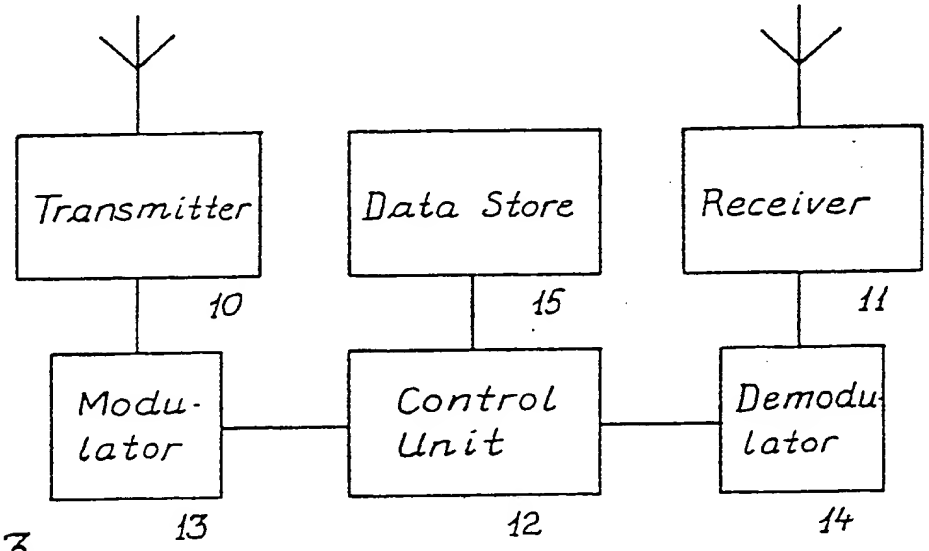

Fig.3

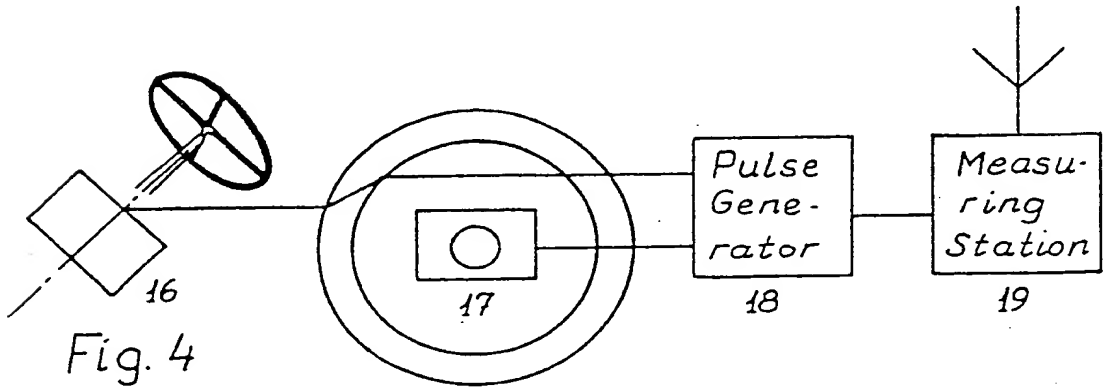

Fig. 4

INTERNATIONAL SEARCH REPORT

International Application No PCT/DK83/00003

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC 3

G 01 S 5/10

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
IPC 3	G 01 S 5/00,/02,/10,/12,/14,/18
US Cl	343:5, 105, 112

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

SE, NO, DK, FI classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Cat.	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X	US, A, 3 774 215 (REED R) 20 November 1973	1-4
X	GB, A, 2 013 062 (WEISSER W) 1 August 1979	1-4, 11
A	US, A, 3 715 758 (SENDER F) 6 February 1973	
A	US, A, 3 848 254 (DREBINGER K ET AL) 12 November 1974	
A	DE, A1, 2 937 900 (SIEMENS AG) 9 April 1981	

* Special categories of cited documents: [15]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
1983-04-08	1983 -04- 15
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